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By Theodore Horton, Assoc. M. Am. Soc. C. E.

Presented March 6th, 1901.

WITH DISCUSSION.

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The work was done under the direction of William M. Brown, Jr., M. Am. Soc. C. E., Chief Engineer of the Metropolitan Sewerage Commission, and was carried out under the immediate charge of the writer.

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The work was done under the direction of William M. Brown, Jr., M. Am. Soc. C. E., Chief Engineer of the Metropolitan Sewerage Commission, and was carried out under the immediate charge of the writer.

The portion of the work herein described consisted of three series of observations made in the channels of the North Metropolitan system, below the Charlestown and the East Boston pumping stations. The first series was made in 1896, soon after the pumping stations and systems at these points had been put in operation. The next series was made in 1897, after these channels had been in operation about two years, during which time ample opportunities for changes in the carrying capacities had taken place. The third or last series took place in 1900, and was made just previous to the tests of the additional pumping plants recently installed at these stations, in order that a suitable rating of the channels could be made for obtaining the quantity of sewage discharged by the pumps during these tests.

The methods used in carrying out these sets of experiments were, with slight modifications, the same in all cases. An Ellis current meter, with four vanes, and provided with an electrical recording instrument, was used. Previous to each series of observations, it was carefully rated over a course varying in length from 500 to 1 000 ft., and for varying speeds. From these tests a rating chart was constructed for use in the calculations.

The points selected for carrying out these observations were at manholes located some distance below the pumping stations, where the flow was free from any disturbing influence of the pumps. The points were about 800 ft. below the stations, in each case, and were far removed from any changes in alignment, cross-section or grade of the sewer. Below the East Boston pumping station the cross-section of the sewer is a 9-ft. circle of 12-in. brick work, cement-washed, with a hydraulic gradient of 1:3 000. Only one small local connection enters this stretch of sewer. No changes in grade occur within a distance of 7 000 ft. below the pumping station. At a point 2 000 ft. below the pumping station, there is a change from a circular section to a horse-shoe section of the same equivalent area. This section continues for a distance of 2 000 ft. and then returns to a circular section. Below the Charlestown pumping station, the cross-section of the sewer is 6 ft. x 6 ft. 8 ins., basket-handle, of 8-in. brickwork, cement-washed, with a hydraulic gradient of 1:2 000. The cross-section and grade are uniform for a distance of about 5 000 ft. below the pumping station, and no local connections enter the sewer within this distance.

In order to determine whether the change of section in the East

Boston channel would have any appreciable effect on the flow in the circular section above it, simultaneous observations of depth were made along this channel for various rates of pumping. These measurements showed that no sensible variation of depth of flow occurred, except near the point where the cross-section changes; and that, for the stretch of channel where the observations were carried on, the flow line and invert were sensibly parallel. Such a study, below the Charlestown pumping station, was not deemed necessary, owing to the greater length of uniform section and grade.

Before operations in the channel were commenced, careful gaugings of the cross-sections were made; graduated straight-edges, provided with plumb-bobs, were inserted; suitable gauges erected for observing the depth of flow in the channel; and a platform hung in convenient position from which to operate the meter.

For the purpose of determining more exactly the position of the current meter while taking observations, a modification of the usual method of using this form of Ellis meter was adopted. The meter was run upon a $\frac{3}{4}$-in. graduated steel rod, in such a manner that it could be clamped at any desired position along the rod. In taking a reading the meter was immersed, one end of the rod was placed in the current, firmly against the side of the channel, and the other end held firmly in the hand and centered at a definite point on the straight-edge—the straight-edge being secured in a horizontal position across the channel and slightly above its center. In this position the meter rotated freely upon the rod, which in turn could be held in any direction in a plane at right angles to the axis of the channel. The position of the meter could thus be located in the following manner: By a distance along the steel rod from the wetted perimeter in a radial line from the central point on the straight-edge; a vertical position in reference to the horizontal straight-edge, measured vertically by a graduated wire attached to the central axis of the meter; a horizontal distance measured along the graduated straight-edge in reference to the vertical diameter of the channel. It is thus seen that the position of the meter was fixed by three measurements, of which only two were necessary, the third one affording a check. In fact, too much attention cannot be given to this point, especially with channels of moderate size, and in which the variations of the velocity in the cross-sections may be great.

In taking the observations, two men were stationed on the platform, one to hold the meter and rod in the desired position, the other to observe the vertical and horizontal position with reference to the straight-edge. The positions of the meter were usually selected in advance. Beginning with the meter at a distance of 0.25 ft. from the wetted perimeter, individual velocity readings were taken successively at each foot and half-foot to the right and left of the vertical diameter of the channel. The meter was then run up the rod to a distance of 0.5 ft. from the wetted perimeter, and a second set of readings taken to the right and left of the vertical diameter, and so on.

On the surface of the ground a third man recorded the revolutions of the meter by means of a stop-watch and electrical clock register. As an Ellis meter of this type registers only half revolutions, and as the intervals for single readings were sometimes necessarily short, dial readings of the electrical instrument were not used, but, instead, the revolutions were counted directly by means of the stop-watch and by listening to the click of the electrical register. A fraction of a revolution could thus be easily estimated. The interval for each single observation was usually 1 minute, but ranged from 30 seconds to 2 minutes, according to the time available for a complete cross-sectional measurement. If run for a longer interval than 2 minutes, it was found that the interferences from clogging and the interruptions of the electrical recording apparatus became so numerous as to interfere seriously with the measurements.

Between each of the individual readings the meter was taken out and carefully inspected to determine whether any foreign matter had lodged upon it in such a way as to affect its correct registration. The frequency with which such small interferences occurred seemed a serious draw-back at first, but by selecting a suitable time interval, by careful inspection of the meter, by noting carefully any deviation in the initial rate at which the meter registered when first immersed, and by comparing the consistency in the final results, errors from such sources were easily determined. All suspicious readings were, of course, repeated, and frequent check readings were made during a cross-sectional measurement.

Before starting a cross-sectional determination for any given depth, the pumping at the station was maintained at a uniform rate until the flow had become constant and free from any possibility of accelera-

tion or back-water. This was easily determined by frequent gauge readings at the observation manhole, and when uniform flow was once established it was maintained, within close limits, until the desired number of meter readings had been taken. These conditions were easily maintained, except when the pumping was at a rate different from the normal rate of flow in the sewer, in which case the pumps were working against a variable lift and required constant changes in the speed in order to maintain a constant discharge. During observations with low flows, the sewage stored up in the suction sewer was utilized in furnishing an increased discharge for high rates of flow.

In working up the results of these measurements, graphical methods were used entirely. Cross-sections of each channel, to suitable scale, were plotted from the actual gaugings taken in the sewer at the observation manhole.

A separate sheet of cross-section paper was devoted to each sectional measurement, and upon it were plotted the sewer section, the straight-edge, the average water line, and the various positions of the current meter during the sectional measurement, with the corresponding velocities computed from the field notes and rating chart. Vertical and horizontal lines were then drawn so as to include as many positions of the meter as possible, and, by means of these, suitable horizontal and vertical velocity curves were constructed. The method previously described for placing the meter in position, during the observations, brought most of the positions of the meter on vertical lines at even distances on each side of the vertical diameter. This was not the case with the horizontal lines, although the points lie sufficiently close to the selected horizontal lines to approximate closely the desired purpose. From these horizontal and vertical velocity curves, points on the cross-section were obtained, through which iso-velocity curves could be drawn and the fluid prism calculated. It will be seen that such a set of auxiliary horizontal and vertical curves gives independent locations of points for the iso-velocity curves, and, when there was any apparent disagreement, the mean location of the point was adopted.

This method of developing a sectional measurement is shown in detail in Fig. 1, the upper set of diagrams corresponding to No. I of the Charlestown series of 1900, and the lower set to No. IV of the East Boston series of 1900.

METROPOLITAN SEWERAGE, SHOWING VERTICAL AND HORIZONTAL VELOCITY CURVES, ISO-VELOCITY CURVES AND CURVE OF INTERNAL FRICTION.

CHARLESTOWN CHANNEL; 6′ 0″ x 6′ 8″, BASKET-HANDLE SECTION; GRADE 1:2000.

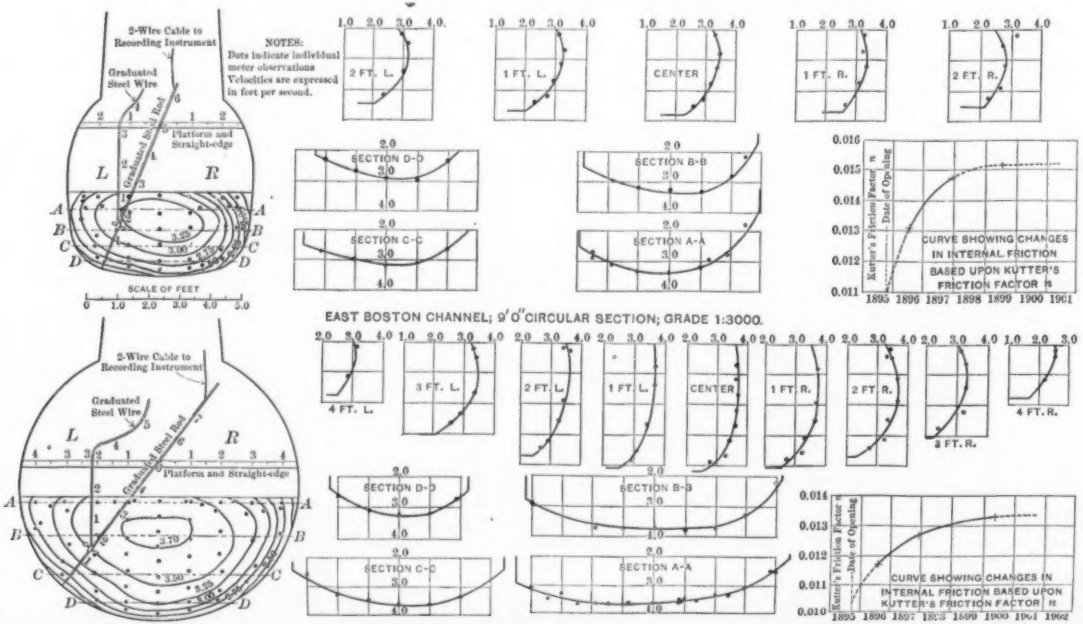

FIG. 1.

The volumes of the fluid prisms were computed according to the prismoidal formula, and the results were tabulated and compared with the Kutter formula according to values of n. From a comparison of these values, a suitable value of n was then selected, from which, with the geometrical elements of the cross-section, a discharge table could be constructed for use at each pumping station.

The results of these observations, arranged in series according to the periods at which the observations were made, are shown in Table No. 1.

TABLE No. 1.

SERIES OF JULY, 1896. CHARLESTOWN PUMPING STATION.

No.	Depth.	Q. in cubic feet per second.	Mean velocity.	Hydraulic radius.	C.	n.
I.....	1.02	8.60	1.99	0.688	107	0.0129
II.....	1.44	16.59	2.46	0.958	112	0.0131
III.....	1.91	26.81	2.82	1.187	115	0.0132
IV.....	2.40	38.82	3.13	1.387	118	0.0133
V.....	2.89	52.90	3.44	1.539	124	0.0130
SERIES OF JULY, 1896. EAST BOSTON PUMPING STATION.						
I.....	1.02	6.10	1.58	0.619	110	0.0122
II.....	1.52	15.67	2.21	0.928	126	0.0117
III.....	2.04	29.40	2.70	1.208	134	0.0116
IV.....	2.45	42.18	3.03	1.408	139	0.0115
V.....	3.16	69.50	3.48	1.830	141	0.0117
VI.....	3.75	94.60	3.73	1.999	145	0.0116
VII...	4.62	138.00	4.18	2.309	150	0.0115
SERIES OF DECEMBER, 1897. CHARLESTOWN PUMPING STATION.						
I.....	2.91	45.67	2.97	1.540	107	0.0149
II.....	3.29	56.14	3.16	1.650	111	0.0147
SERIES OF NOVEMBER, 1897. EAST BOSTON PUMPING STATION.						
I.....	2.15	30.13	2.55	1.280	123	0.0126
II.....	2.74	47.75	2.90	1.560	127	0.0127
III.....	3.19	62.05	3.06	1.762	126	0.0129
IV.....	3.20	64.82	3.18	1.771	131	0.0126
SERIES OF JUNE, 1900. CHARLESTOWN PUMPING STATION.						
I.....	2.29	30.82	2.66	1.342	102	0.0151
II.....	2.78	41.39	2.86	1.508	104	0.0152
III.....	3.26	52.96	3.04	1.645	106	0·0152
SERIES OF APRIL, 1900. EAST BOSTON PUMPING STATION.						
I.....	1.99	24.96	2.38	1.120	119	0.0130
II.....	2.83	48.26	2.82	1.606	121	0.0132
III.....	3.64	76.78	3.16	1.952	124	0.0133
IV.....	4.18	95.84	3.30	2·130	124	0.0136

In July, 1896, the system at these points had been in operation about 10 months, and the masonry was in almost its original condition. The sides of each sewer, above and below the average water line, were covered with a thin coating of grease of a leaden color, and supported an organic growth—probably of a fungus nature, as probably no light ever entered the sewer, except temporarily.

The condition of the sewers in November and December, 1897, after a continuous service of 2 years and 2 months, was similar to that at the time of the 1896 observations. There were slight incrustations at frequent intervals, due to barely visible seepage of ground-water, and the growth, though not much heavier, covered a greater area on the sides of the sewers.

The condition of the channels in April and June, 1900, after a continued use of 3 years and 9 months, was not much different from that which obtained during the 1897 observations. The incrustation seemed to be slightly greater, but the organic growth did not show any marked increase over that present in 1897.

A discussion of any observations such as these should be made with caution, and the following remarks are offered more as suggestions than as the writer's views. It will be seen, first, from a hydraulic standpoint, that the results of the individual observations of any one series show a slight lack of uniformity, and, when compared according to values of n, do not arrange themselves in any definite order. This may be due to slight inaccuracies, from various sources, in dealing with a fluid of the nature of sewage; or to relative variations in the condition of the internal surfaces at the different depths of flow; or, perhaps, to the variation in the composition of the sewage itself. However this may be, it is found that if the different series themselves be compared, these slight differences fade in importance, and the results show a much greater uniformity. This is illustrated more clearly in Table No. 2, which gives the average values of n, in the three series, for each channel, arranged in the order of time.

TABLE No. 2.—VALUES OF n FOR THE CHARLESTOWN AND EAST BOSTON CHANNELS.

	1896.	1897.	1900.
Charlestown channel	0.0131	0.0148	0.0152
East Boston channel	0.0117	0.0127	0.0133

If the results in Table No. 2 be plotted, as shown in the diagrams on Fig. 1, with the horizontal scale representing time intervals from the date of opening of each system, and the vertical scale representing the tabulated values of n, and a curve be sketched through them, we might generalize as follows:

(1) Both curves are similar; the Charlestown channel curve being the steeper, and indicating a greater change in internal friction.

(2) Both curves show a sharp rise near the origin, indicating that the greatest change in internal surface took place soon after the channels were put in operation.

(3) That if the curves be projected back to the vertical axis, they show roughly the same initial coefficient of friction n, between 0.010 and 0.011, the Charlestown channel giving slightly the higher value.

In comparing these changes in the values of n with the actual condition of the channels, it should be kept in mind that the East Boston channel is of 3 ft. greater diameter than the Charlestown channel, that the invert of the East Boston channel is approximately 3 ft. above mean low water, while the Charlestown channel is 4 ft. below mean low water, and that the East Boston channel receives relatively less storm water than the Charlestown channel, and is, consequently, subject to less fluctuation of water surface. The importance of this last influence is evident from the fact that the deposit of both grease and organic growth appeared in greater abundance on the sides of the channels, and was greatest near the line of average flow. On the bottom of the channel there was practically no deposit; resulting, no doubt, from the scouring action of sand and other heavy particles transported along the invert by the sewage. This last feature is by no means novel, and has frequently been observed, though to a less extent, in water-supply conduits.

The effect of the density of the sewage upon the carrying capacity of these channels appears to be slight, in view of the fact that the observations were made under all the varying conditions of storm and dry-weather flow. The possible effect of cleaning or scraping, however, might be much greater, but, at this date, no cleaning of any sort has taken place in these channels. Such questions, with others of equal interest, will, it is hoped, have more light thrown upon them by the future continuance of this work.

DISCUSSION.

Mr. Hering. RUDOLPH HERING, M. Am. Soc. C. E.—Papers of this nature are of special value because they add to the fund of knowledge by giving the results of experiments made on a large scale in a field where there is a dearth of exact information. In very few sewers has the flow been carefully gauged, and, for practical purposes, data derived from the flow of clean water are generally used. It is, therefore, especially gratifying to see a paper on this subject. The information it contains seems to be reliable, and, if so, it is certainly useful.

Presumably, the meter was rated in clean water instead of sewage, and, to avoid clogging during the gauging, the meter is said to have been withdrawn every two minutes. The chief trouble in gauging sewage is caused by the suspended matter catching in the wheel and retarding its motion. The speaker would like to know how far this feature was considered, and how far the results obtained can be applied to other cases.

The lining of the sewers was apparently the same in both instances; namely, cement-washed brickwork. Yet the coefficients of resistance were different, apparently due to the fact that there was a greater rise and fall in the water level in one case than in the other, consequently a greater accumulation of matter adhering to the sides of the sewer and a greater resistance to the flow. The importance of the adhering matter as affecting the velocity is, therefore, clearly indicated.

The hydraulic slope seems to have been assumed as being the same as the slope of the invert. What effect was, then, caused when the section changed, and was any observation taken of this effect? Calculating the discharge by the prismoidal method is unusual but very good.

The small diagrams show the changes of the internal friction with age. A similar change takes place even with clean water, and in open channels as well as in pipes. It indicates the usefulness and rationale of having a coefficient depending substantially on surface friction alone, so that this change may be separately and properly accounted for in the formula used. In extending the curve from the known points back to the time when the sewer was built, the speaker thinks that the curve is dropped too low. New brickwork under similar conditions does not, as a rule, give so low a coefficient, but generally ranges from 0.011 to 0.012, instead of from 0.0105 to 0.011. Therefore, it would seem better to have drawn a tangent than a curve from the last point of observation to the ordinate representing the condition of the sewer when new.

In a Colorado city the speaker noticed at one time so large an accumulation of slimy growth attached to a pipe that when loosened by a flush it caused a complete stoppage. In Philadelphia, near Girard Bridge, he noticed in a 4-ft. sewer such a coating, consisting

Mr. Hering. of mycelium, that was more than 1 in. thick at the soffit. It was soft and gelatinous.

Mr. Smith. J. WALDO SMITH, Assoc. M. Am. Soc. C. E.—It is rather gratifying to see how well the results obtained by Mr. Horton seem to agree with the results of the flow of water in large riveted steel conduits. That is to say, the first deterioration is of considerable amount and very rapid, and afterward the deterioration seems to be much slower, but continues for years. The speaker would be glad to learn just why a thin coating of slime should so greatly increase the friction. The fact is undisputed that the loss in carrying capacity due to this is very great, and in some cases under the speaker's immediate notice this loss has in four years amounted to over 20% of the original carrying capacity; one-half to two-thirds of this loss probably occurring in the first year. Mr. Horton's general results seem to show that the same is true of a cement-washed brick sewer.

Mr. Tillson. GEORGE W. TILLSON, M. Am. Soc. C. E.—Mr. Hering's remarks remind the writer of an experience he had in Omaha, of practically the same nature. The sewer system originally built there in 1881 or 1882 was made up wholly of vitrified pipe, the laterals all being 6-in. They were short, those first built extending, probably, not more than half a mile; the lower two-thirds having a grade of about 6 ins. in 100 ft., and the remainder anywhere from 4 to 8 ft. in 100 ft. The upper end was provided in every case with a flush-tank, but these worked very irregularly, and, probably for weeks, not at all. The system was built entirely without manholes on the laterals, and, after the sewers had been in use perhaps 1½ or 2 years, the laterals on which the greatest number of connections had been made became clogged, and gave a great deal of trouble. It was necessary to dig down and open the pipe, and then this growth that Mr. Hering speaks of was discovered. It extended practically through the whole length of the sewer, where the grade was light. The part where the residences were had very few connections. The only way the sewers could be cleared out was by digging down at intervals of perhaps 250 or 300 ft., putting a float through and then dragging a ball after it. A great deal of attention was required to keep the sewers clear, and, eventually, manholes were built every 364 ft., and the sewers were kept clean by flushing, until the connections became so numerous that it was necessary to rebuild the sewers and put in 18-in. pipes, after which there was no trouble at all. But it does seem that, in these small pipe sewers, unless there is sufficient flush to keep them approximately clean, there will be this growth on the inside of the pipes, which will materially reduce and almost entirely destroy their efficiency.

Regular flushing, however, will keep them clean. The sewers which were built afterward, where the flow was slight and where there were better regulated flush-tanks, gave no trouble at all.

The growth referred to was a sort of fungus of the streamer style, perhaps 5 or 6 ins. long, and very bulky when it was first taken out, but after exposure to the air it would dry up and almost disappear. Mr. Tillson.

G. C. WHIPPLE, Assoc. M. Am. Soc. C. E.—The speaker cannot, of course, tell just what organisms were growing upon the walls of this particular sewer without making an examination, but, in order that it may be placed as a matter of record in connection with the paper, he will be very glad to make an examination of any material which the author may send him, and transmit the results by letter. Mr. Whipple.

The organisms which grow in sewers are very different from those which grow in water pipes. Speaking broadly, it may be said that those found in water-pipes belong to the animal kingdom, while those found in sewers are vegetable forms of a very low type. In water-mains we have the fresh-water sponges and several genera of *Bryozoa*, such as *Plumatella*, *Fredericella*, *Paludicella*, etc.; organisms which require oxygen, and which, for their food, depend upon the microscopic organisms found in water. It has been found that a large amount of suspended matter, however, is prejudical to their growth, as it clogs up their minute pores. For this reason sponges and *Polyzoa* are found upon the top and sides of pipes rather than upon the bottom. It is easy to see, therefore, how the suspended particles and greasy substances found in sewage would tend to prevent these organisms from becoming fixed upon the walls of sewers. So far as the speaker has examined deposits in sewers he has never found any of the sponges or *Bryozoa* (*Polyzoa*) present.

The organisms which most abound upon the walls of sewers, and upon the sides of tanks through which sewage passes, belong to the fungi—plants which have no chlorophyll and no starch. Lacking these, they are unable to assimilate inorganic matter, and, consequently, have a saprophytic or a parasitic existence; that is, they live upon dead organic matter or upon some living host. Most of the fungi consist of two parts, the mycelium and the fruit. The mycelium is the vegetative portion of the plant, and is often a mass of delicate, jointed, branched, colorless filaments intertwined to form a cottony or felty layer. It is these mycelia which grow luxuriantly upon the walls of receptacles containing sewage. The fruit consists of certain terminal filaments erected from the general mass and bearing spore-cells of various kinds. It is chiefly by differences in the method of fruiting that the different fungi are distinguished from each other. Hence, when only the mycelium is to be found, it is difficult and often impossible to identify the specimen. Of those fungi most commonly found in sewers, may be mentioned: *Leptothrix*, *Cladothrix*, *Beggiatoa*, *Mucor*, *Penicellium*, *Aspergillus*, *Saprolegnia*, *Leptomitus*, *Achlya*, *Saccharomyces*, etc.

*On March 19th, 1901, the writer received from the author three

*The remainder of this discussion was received from Mr. Whipple by letter.

Mr. Whipple. samples of material taken from the walls of the sewer. These were examined microscopically with the following results:

Sample No. 1.—"Coating scraped from sides of sewer. When in place it consists of a layer of black material $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, attached to the wall, and this is covered with a thin gray coating, which gives the gray appearance to the sewer."

The black mass is essentially a mass of bacteria interlaced with threads of *Beggiatoa* and mold hyphæ. The black color is due chiefly to sulphur compounds, held, perhaps, by the *Beggiatoa*. Many of the bacteria were in the zoöglœa state, but many cells were seen singly, in pairs and in chains. *Spirilla* were common. Many yeast-cells (*Saccharomyces cerevisiæ*) were present, and a few grains of starch and globules of fat. The gray surface coating consists chiefly of interlaced mycelium threads. These are in part mold hyphæ and in part threads of *Leptomitus*. One branch of *Penicillium* was observed in fruit. A few microscopic organisms, such as *Trachelomonas*, *Melosira*, *Rotifer*, etc., were found entangled in the mass.

Sample No. 2.—"Sample of the gray coating separated from the surface of the black material mentioned under Sample No. 1. It was about $\frac{1}{32}$ in. thick."

As mentioned above it consisted of interlaced mycelium threads, with yeast cells, starch grains and *Beggiatoa* filaments, with bacteria covering all. In this sample there were many ciliated infusoria, such as *Glaucoma*, *Halteria*, *Trachelocerea*, *Paramœcium*, etc.

Sample No. 3.—"Sample of streamers which are attached to the coating on the sides of the sewer, and which float out into the stream."

These consisted chiefly of *Leptomitus*, the common "sewage fungus." The hyphæ of *Leptomitus* are long, cylindrical, branched, and deeply constricted at intervals and at the point of branching. Near the constriction there is usually a globular body, like an oil-globule. The grayish protoplasm generally occurs as evenly distributed lumps, but sometimes it is arranged in concentric masses. The zoospores are formed in club-shaped terminal sporangia. A few of these sporangia were observed in the sample. The hyphæ are practically colorless.

Leptomitus often develops in great masses upon the walls of sewers and on the banks of polluted streams. The writer has several times seen it forming layers from 5 to 8 ins. thick, and it is easy to believe that small pipes may be almost completely choked by it. Apparently, it grows best in the absence of oxygen, and in this respect it agrees with some of the *Schizomycetes*.

Sample No. 4.—"General deposit from material on sides of sewer."

The bulk of this deposit consisted of a mass of small worms embedded in amorphous matter of bacterial origin. Mold hyphæ were abundant, but there was little *Leptomitus*. Several fragments of paper and a small piece of cloth were found, besides several fibers of wool, pieces of straw, etc. This sample contained more microscopic organisms than the others.

THEODORE HORTON, Assoc. M. Am. Soc. C. E. (by letter).—The discussions on this paper have been more in the nature of additions than of differences of opinion, hence the writer feels that he can add little of interest to what has already been said. A few points were brought up informally, however, which have not yet been presented and which may be worthy of mention. Mr. Horton.

The first of these relates to the method, adopted in these measurements, of operating the current meter from a fixed platform in the sewer, the locations of the meter being obtained by a system of rectangular co-ordinates, as compared with other methods adopted successfully elsewhere, notably in the Sudbury Aqueduct experiments, in which the meter was operated from a framework in an observation manhole, the locations of the meter being obtained by a system of polar co-ordinates. The choice, in the present case, was dependent upon the nature of the fluid conveyed in the channel, for with sewage the suspended matter was of such a nature and in such quantities as to necessitate frequent inspections and occasional cleaning of the current meter, in order to insure correct registration. The suspended matter occasionally met with in conduits conveying water is, on the contrary, usually of such a nature as to be readily screened, and any trouble from clogging of the meter is avoided. It was these frequent withdrawals of the meter during a sectional measurement which, it was thought, were more easily and quickly made by the method of operation adopted than by the other method which, though very efficient, was slightly more complicated. Incidentally, also, the operation of a meter from a framework involves the necessity of a certain amount of working space in a manhole. In the present case the space was somewhat limited and might have proved inadequate.

A second point, and one which bears slightly upon the same question, was in regard to operating the meter from a pivotal position near the center of the cross-section. This is somewhat important, considering the type of meter used in these measurements, for with an Ellis meter the motion depends upon the difference of pressure on the two sides of the cup-shaped vanes. If, then, the meter is placed in a stream where the filaments are parallel and travel with the same velocity, we have the conditions equivalent to those under which the meter is rated in still water. If, however, the filaments which impinge against the vanes move with varying velocities, an erroneous mean velocity for the central point of the meter is recorded. This influence, of course, is inappreciable in streams of large cross-section where the variations of velocity in the cross-section are very gradual, but in closed channels of moderate size these variations are more sudden, especially near the periphery, and the possibility of error is consequently greater. By operating the meter from a pivotal position, however, as was done in these measurements, the plane of the revolv-

Mr. Horton. ing vanes is, for nearly every position of the meter in the cross-section, tangent to the iso-velocity curves, so that the velocity recorded by the meter in any such position is, so far as this one influence is concerned, a correct one. Near the surface of the stream, where the iso-velocity curves are nearly horizontal, this influence was avoided by holding the meter in a horizontal position.

Many questions of interest from a biological standpoint suggest themselves, especially if the composition of sewage is contrasted with that of fresh water. Normally, sewage has an abundance of organic food supply and little or no dissolved oxygen. It abounds in organisms of a fungous nature which develop without the direct action of sunlight, and many of them without dissolved oxygen. Fresh water, on the contrary, has relatively a small amount of organic food supply and usually an abundance of dissolved oxygen. It supports normally a limited growth of organisms. Such organisms are almost wholly green plants which are dependent upon the direct action of sunlight for their development. These, when they reach the closed dark water-supply conduits, probably cease to develop.

In channels conveying sewage there is a marked increase in the filamentous growths on the sides of the channels during the summer months, due, no doubt, to the increased temperature of the sewage at this season. This increase of growth was quite noticeable in some portions of the Metropolitan sewers, and many instances have been cited where such growths have been sufficiently abundant to completely close the channel. In water-supply conduits this seasonal development of organisms is probably also active to a degree, but is probably much diminished by the fact that the organisms normally conveyed into the conduits are, owing to the darkness, in an environment unfitted for any further development. In fact, the troubles so often caused by growths in such conduits are usually due to abnormal conditions, and are rarely found in well-maintained water supplies. The main point, however, is that these growths, when they do occur, cause increased internal friction and a consequent decrease in the carrying capacity of the channels.